Xact® 920 Continuous Water Analyzer: Application Note

COOPER ENVIRONMENTAL
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Pathogen Removal and High Log Reduction Value Crediting for Reverse Osmosis Systems Using Continuous Strontium Monitoring – 2021

Public potable water supplies are being stressed by growing population, cyclical droughts, and climate change. One way to sustainably augment the potable water supply is to recycle (reuse) wastewater. This is performed by using a tertiary wastewater treatment facility followed by advanced water purification (AWP) which includes; Reverse Osmosis (RO), UV/ advanced oxidation and free chlorine disinfection. RO is the core technology of AWP providing a physical barrier to waterborne pathogens and dissolved constituents. Reliable and safe potable reuse requires continuous demonstration of pathogen removal. Since monitoring pathogens directly is prohibitively time consuming, removal is typically demonstrated using total organic carbon (TOC) and electrical conductivity (EC) as a surrogate. TOC and EC offer a maximum achievable log reduction value (LRV) of approximately 2 and 1.5, respectively. Where under controlled conditions measuring actual pathogens, RO systems provide at least a 4-log reduction. Prior research studies* show that strontium, a naturally occurring constituent, has a 3.0 – 3.5 LRV for RO systems. Strontium's higher LRV allows RO systems to receive more accurate treatment credits and allows increased sensitivity to RO membrane breaches.

This application evaluates the feasibility of demonstrating continuous RO pathogen removal by measuring strontium using Cooper Environmental's Xact® 920, a continuous multi-metals monitor based-on energy dispersive X-ray fluorescence (XRF).

Data presented in this paper was collected over a two-month demonstration in 2021, with the Xact® 920 configured to provide continuous 1-hr strontium measurements. The Xact® 920 was installed at a pilot AWP facility capable of treating 100,000 gallons per day. The pilot plant was equipped with a 2-stage primary (PRO) and closed circuit secondary (CCRO) RO system which together achieves greater than 90% recovery. One Xact® 920 was installed with an automatic switching manifold, allowing switching between four sample locations including: PRO Feed, PRO permeate, CCRO Feed (PRO Brine) and CCRO Permeate. Measuring these four locations allows LRV calculations (Equation 1) for both the primary and secondary RO systems. Figure 1 show the AWP RO treatment process and the Xact® 920 sample locations.

$$LRV = Log(C_f) - Log(C_p) \qquad \text{Equation 1}$$

Where:

LRV = log removal value
C_f = strontium RO feed concentration
C_p = strontium RO permeate concentration

* Trussell, R. S., et al. (2017). *Realizing reverse osmosis potential for potable reuse: Demonstrating enhanced pathogen removal (report 196).* Washington, DC: Department of the Interior Bureau of Reclamation.

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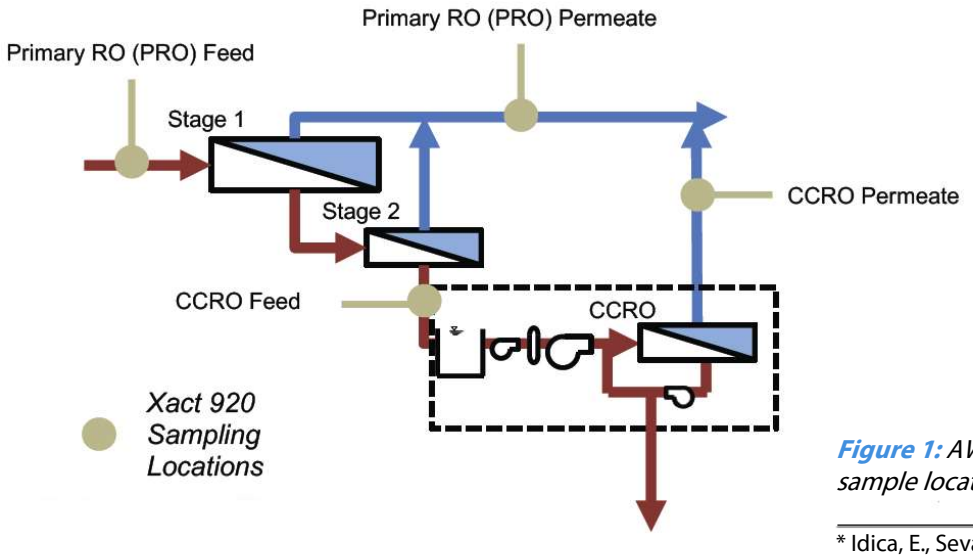

Figure 1: *AWP RO treatment process and Xact® 920 sample locations*

* Idica, E., Seval, S. *Online Strontium Meter for Potable Reuse RO LRV Crediting*. 2021 WateReuse California Annual Conference, September 19th, 2021.

The Xact® 920's performance was evaluated based on adequate sensitivity (detection limit), mass balance of the PRO system, and comparing the Xact® 920 to U.S. EPA's Method 200.8, an inductively coupled plasma mass spectrometry (ICP-MS) based method, for total strontium concentration and LRV.

The Xact® 920's 99% confidence level detection limit (DL) for all four streams was calculated. Table 1 shows the Xact® 920's DLs along with the average concentration and standard deviation for all four sample steams collected during the study. The closest Xact® 920 DL is over four standard deviations from the average concentration. Meaning greater than 99.99% of all strontium measurements will be greater than the Xact® 920's DLs. This demonstrates the Xact® 920 has adequate sensitivity for this application.

Table 1: *Summary of Xact® 920 strontium DLs compared to the average measured total strontium for all four samples*

Sample ID	Xact® 920 DL (ppb)	Xact® measured strontium concentration (ppb)		
		N	Average	Standard deviation
PRO feed	4.6	92	669	39
PRO permeate	0.22	116	0.69	0.11
CCRO feed	6.8	80	2664	142
CCRO permeate	0.48	223	2.68	0.38

Strontium mass balance/recovery of the PRO system was calculated using Equation 2 on four separate days. The mass of the strontium on the permeate and brine streams should equal the mass on the feed. The average strontium recovery was 99% ± 3%, demonstrating the Xact® 920 strontium measurements are in the expected range.

$$Sr\ mass\ recovery = \frac{[(C_p \times F_p) + (C_b \times F_b)]}{(C_f \times F_f)} \times 100\% \qquad \text{Equation 2}$$

Where:

C_p = strontium PRO permeate concentration
F_p = PRO permeate flow rate
C_b = strontium PRO brine concentration
F_b = PRO brine flow rate
C_f = stontium PRO feed concentration
F_f = PRO feed flow rate

The Xact® 920 measurements were compared to laboratory results using EPA 200.8 for both concentration and LRV. Table 2 shows the average percent difference between the Xact® 920 and EPA 200.8 for total strontium concentration, during three sampling campaigns. In addition, one inter-laboratory

EPA 200.8 comparison was conducted on all four streams to evaluate the variability of EPA 200.8. The Xact® 920 had excellent agreement with EPA 200.8 exhibiting similar percent differences as EPA 200.8 has with itself.

Table 2: *Xact® 920 percent difference analysis to EPA 200.8 for total strontium – concentration*

Average Percent Difference		
Stream ID	200.8 inter-laboratory comparison	200.8 & Xact® 920
PRO feed	1.4%	8.6%
PRO permeate	16.9%	19.6%
CCRO feed	13.3%	9.2%
CCRO permeate	3.0%	10.5%

The same data used for percent difference analysis in total strontium concentration was also used to calculate the LRV for the PRO and CCRO systems. Table 3 summarizes the measured LRVs for the Xact® 920 and EPA 200.8, while Table 4 shows the percent difference analysis for the LRV. The Xact® 920 performance was equal to EPA 200.8, demonstrating the Xact® 920 can be used for this application.

Table 3: *Summary of Xact® 920 and EPA 200.8 LRV for the PRO and CCRO systems*

System ID	Campaigns (n)	Average Percent Difference			
		Avg. Xact® 920	Stdev Xact® 920	Avg. 200.8	Stdev 200.8
PRO	3	2.97	0.04	2.93	0.11
CCRO		3.04	0.15	3.05	0.16

Table 4: *Xact® 920 percent difference analysis to EPA 200.8 for total strontium – LRV*

LRV – Average Percent Difference		
Stream ID	200.8 inter-laboratory comparison	200.8 & Xact® 920
PRO	2.3%	2.9%
CCRO	1.5%	1.3%

Lastly, a membrane breach was simulated on the CCRO system to evaluate if the Xact® 920 could detect such an event. Figure 2 shows the Xact® 920 and EPA 200.8 total strontium measurements over time during the breach event. The Xact® 920 and EPA 200.8 track very closely during normal operation and under a simulated breach.

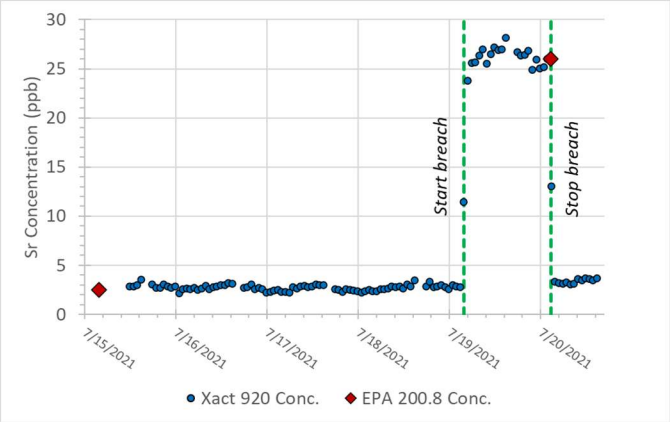

Figure 2: *Xact® 920 and EPA 200.8 total stronium concentration results during a simulated breach of the CCRO system*

This application demonstrates the Xact® 920 can provide accurate, continuous, near real-time total strontium measurements to demonstrate adequate pathogen removal and high LRV crediting of RO systems.

> *For more information about the Xact® 920 technology, please contact Cooper Environmental at info@sci-monitoring.com*